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BOWLDER-PAVEMENT AT WILSON, N. Y.

BOWLDERS in till when groupt in an approximately horizontal plane and striated on their upper surfaces in a common direction constitute a bowlder-pavement.[1] Considerable attention has been given to such pavements in Scotland, especially by the Hugh Millers, father and son. In 1859, O. N. Stoddard described a fine example near Miami University, O., but no other American observations have come to my attention.[2] While engaged, last summer, in field work of the United States Geological Survey, I came upon another example, which seems worthy of record.

The village of Wilson is situated about twelve miles east of the Niagara River and half a mile from the shore of Lake Ontario. One of its main streets runs to the shore, where a short pier juts into the lake. There are longer piers a little farther west at the mouth of Twelvemile Creek. On this part of the lake coast the movement of shore drift is from west to east, and this movement is locally obstructed by the piers. West of the piers there is an accumulation of shore drift, and the land gradually encroaches on the lake. East of them the defect of shore drift deprives the shore of its natural protection, and erosion is exceptionally rapid. At the Wilson pier the bluff due

[1] This is the usage of the Scottish geologists. The term has been employed in another sense by J. W. Spencer; see explanation of plate, p. 775.

[2] Diluvial Striæ on Fragments in Situ, by O. N. STODDARD. Amer. Jour. of Sci., 2d Ser., Vol. XXVIII, pp. 227–228.

Unpublisht observations by H. L. FAIRCHILD and M. R. CAMPBELL indicate allied phenomena at Rochester, N. Y., and Cleveland, O.

to the attack of the waves is twelve to fifteen feet high and free from talus, and the section is fully exposed for a half mile to the east. The lower part of the bluff is composed of till, eight to ten feet being visible, and the base not seen. Above this is laminated clay, a deposit spread by the waters of the glacial lake Iroquois.

To casual observation the till appears to be a single continuous body, but more careful examination shows that there are two parts separated by a horizontal line between five and six feet above the surface of the water. Both tills are reddish-brown, but there is a slight difference in color, the upper inclining toward orange and the lower toward purple. At various points a bitter efflorescence was seen on the surface of the upper till, and this was not observed on the lower. Both tills are moderately supplied with pebbles and bowlders, the material of the larger fragments being chiefly sandstone and limestone of the subjacent Medina and contiguous Hudson River formations, and ranging in diameter up to about twenty inches. There are also crystalline erratics from a distance, and a few of these are several feet in diameter. Such larger bowlders were not seen in situ in the bluff, but occur here and there on the beach and in shallow water near the shore, where they have evidently been left by the erosion of the enclosing till.

Just at the top of the lower till bowlders are comparatively abundant, and such as are flat lie with their greater dimensions horizontal. Their upper surfaces form parts of a level line drawn across the bluff (Plate XIV), and it was their alignment which drew attention to the compound character of the till. So far as the upper till betrays structure, its lamination is approximately horizontal. Much of the lower till is somewhat definitely laminated, and the lamination is contorted. In some places there are irregular masses of gray till mingled with the red, the general arrangement being suggestive of structures commonly seen in the Archean complex.

Examination showed nearly all the bowlders at the plane of separation to be striated on their upper surfaces. The directions

1

3

2

4

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of striation were observed in the cases of ten bowlders in situ, and found to be substantially parallel. Nine ranged between S. 45° W. and S. 50° W., and the tenth was S. 55° W. The accompanying illustrations (Pl. XIV, Figs. 1, 2, and 3) show the upper faces of two of the bowlders and the side of one. It seems clear that after the deposition of the lower till it was over-ridden by a glacier moving toward the southwest. This is the general direction of striation on the bed rock of the region, but no observation was made in the immediate vicinity of Wilson.

All the bowlders strongly glaciated on their upper surfaces were found to have one diameter less than the others, and to lie in such position that the least diameter was vertical. So far as observed, bowlders without pronounced differences in their several diameters were not more strongly glaciated on the upper side than on other sides, although lying at the same level as the others.

To account for these peculiarities, as well as for the accumulation of bowlders at the summit of the lower till, the following explanation is offered: The glacier which deposited the upper till slowly eroded the lower till as it moved over it. When this erosion began to uncover a bowlder, differential pressures resulted. In Fig. 1 the horizontal line represents the upper sur-

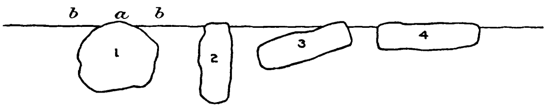

FIG. 1. Diagram illustrating theory of bowlder arrangement.

face of the till undergoing erosion, and 1 the discovered bowlder, projecting above the till at *a*. If the glacier were stationary it would mold itself plastically about this protuberance and press equally on *a* and *bb*, but as it is in motion and has great viscosity, the pressure is greater at *a* than at *bb*, and the differential pressure is not merely momentary, but continuous. It has the effect of a simple pressure on the bowlder at *a*, forcing it down into its plastic matrix, and as the erosion of the till continues,

the bowlder is steadily pusht downward. The erosion is thus rendered selective, the bowlders remaining as the fine material is carried away. The bowlders accumulated at the surface of the lower till are a residuum from the portion of the till which has been removed.

Combined with the vertical pressure at *a* is a horizontal pressure (from forward motion of glacier) tending to rotate the bowlder in its matrix. In the case of a rounded bowlder there may be rotation as long as it continues to be forced downward, but a flat bowlder eventually reaches an attitude of stability. If the longer diameter lies originally vertical or oblique (2 or 3, Fig. 1), there is a partial rotation bringing it to a horizontal position (4, Fig. 1), and rotation then ceases because the differential vertical pressure is applied to both edges of the rock, and any incipient rotation is checkt by increase of pressure on the rising edge. The horizontal attitude is thus stable, and a bowlder having once acquired it retains it as long as the process continues, being thereby enabled to receive thorough glaciation on its upper face.

If this explanation is correct, a bowlder-pavement records an epoch of local till erosion by a glacier. The epoch may be a mere episode interrupting a period of till deposition by the same glacier, or it may be a part of a stage of readvance following a long interglacial period. The demonstration of two tills at the Wilson locality does not by itself constitute an important contribution to the subject of the complexity of glacial history, for the removal of the upper part of the lower till has destroyed whatever evidence may have existed as to the length of time interval separating the two. The significance of the phenomenon can hardly be understood until it shall have been brought into relation with cognate facts from a broad field.

The observation may perhaps serve a more important purpose by directing attention to the possibility of gathering much information as to the direction and history of ice motion from the internal structure of till sheets. The second Hugh Miller not only found a body of information in bowlder-pavements, but

discovered that in certain Scottish and English tills the elongated fragments, large and small, are oriented in the direction of ice motion, so that he was often able from direct examination of the till to determine the direction of the ice current by which it was deposited.[1]

A bowlder-pavement, doubtless continuous with the Wilson, was seen at the lake shore, three miles west of the village, the plane of separation being two or three feet above the water level.

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EXPLANATION OF PLATE.

FIGS. 1, 3. Glaciated faces of bowlders from bowlder-pavement. $\times \frac{1}{7}$.

FIG. 2. Side of the bowlder represented in Fig. 1, showing even truncation of glaciated face. $\times \frac{1}{7}$.

FIG. 4. Till and bluff at Wilson, showing line of bowlders at horizon of bowlder-pavement. Sketch by H. H. Nichols, based on a photograph.[2]

[1] On Bowlder Glaciation, by HUGH MILLER, Proc. Roy. Phys. Soc. of Edinburgh, Vol. VII, pp. 156–189, 1884. This paper summarizes earlier literature, and is itself probably the most important contribution to the subject.

[2] The strand is thickly set with bowlders releast from the till by wave erosion. For such accumulations J. W. Spencer, doubtless unaware that the term was preoccupied, proposed the title "bowlder-pavement." In each case the term designates a residuum from erosion, the process being in one case glacial, in the other littoral. It chances the view, drawn to show one kind of bowlder-pavement, illustrates the other also.